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**HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII**

Under the joint supervision of the
**UNITED STATES DEPARTMENT OF AGRICULTURE
AND THE UNIVERSITY OF HAWAII**

BULLETIN No. 74

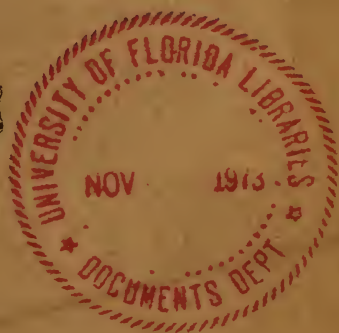
**THE EDIBLE PASSION FRUIT
IN HAWAII**

By

W. T. POPE, Senior Horticulturist



Issued September 1935



**UNITED STATES DEPARTMENT OF AGRICULTURE
OFFICE OF EXPERIMENT STATIONS**

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By W. T. POPE, *Senior Horticulturist*

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INTRODUCTION

Possibly half a dozen species of edible passion fruit have been in cultivation in Hawaii for the last half century. Several of these species have been disseminated in certain localities and are now growing as a part of the natural vegetation. Only comparatively recently has effort been made to grow the fruit commercially in Hawaii. Investigation has shown that it is of relatively easy culture and is well adapted to Hawaiian conditions. The most useful species grow best in the cooler, moist parts of the Tropics, although they are not considered exacting in their climatic and soil requirements.

The relatively small amount of space required by the passion fruit plants and their habit of fruiting early adapt them to temporary intercropping with such permanent orchard trees as require 6 or 8 years to come into regular bearing and need their properly allotted space.

The passion fruit may be used in many ways for food and beverage purposes and it may find a market both in Hawaii and on the mainland of the United States.

No insect pests or plant diseases have yet been reported as seriously attacking passion fruit plants in Hawaii.

The Hawaii Agricultural Experiment Station has been conducting experiments with the edible passion fruit since 1924. The first of these was started at the central station in Honolulu, but field experiments have also been carried on at the Kona substation, Island of Hawaii, since 1931. In addition, many small field tests have been made in cooperation with growers in various parts of the Territory.

Botanical classification, habits of pollination, propagation, and general cultural requirements have also been studied by the station (12, p. 23; 17).¹

BOTANICAL RELATIONS

All passion fruit species belong to the genus *Passiflora*. They are woody, perennial climbers indigenous in tropical America. Most *Passifloras* are ornamentals, but a few are cultivated for their edible fruit. The edible fruit is similar in form to that of certain kinds of melons and of the papaya. Striking examples are the giant granadilla, muskmelon, and the common round-fruited papaya. Early botanists recognized them as of the same great family. Possibly for other reasons, however, they are now classified in separate families—*Passifloraceae*, *Cucurbitaceae*, and *Papayaceae*, respectively. Practically all species of the genus *Passiflora* are characterized by either entire or lobed leaves arranged alternately at nodes along the stem and branches and have simple tendrils from nodes to hold the growing plants in place. The flowers are conspicuous because of unusual form and varying combinations of beautiful colors. The different kinds of edible passion fruit are not only attractive in form and color but are generally pleasing in flavor. The species having edible fruit, now growing in Hawaii, are as follows: Purple passion fruit (*Passiflora edulis*), yellow passion fruit (*P. edulis* forma *flavicarpa*).² sweet granadilla or waterlemon (*P. ligularis*), giant granadilla (*P. quadrangularis*), bell-apple (*P. laurifolia*), West Indian sweet calabash (*P. maliformis*), red-fruited passion vine (*P. foetida*), green-fruited passion vine (*P. ciliata*), white-flowered passion vine (*P. alba*), and inkberry (*P. suberosa*). The last four mentioned have little, if any, value for human consumption but are eaten and disseminated by birds. The maypop (*P. incarnata*) is mentioned as of early introduction to Hawaii by Hillebrand (8, p. 139), but no recent reports have been noted.

POLLINATION HABITS AND UNFRUITFULNESS

Several species of *Passiflora* are irregular in their habits of setting fruit in Hawaii. This is attributed to unsatisfactory pollination. These species are evidently not in an environment similar to that in which they developed in their native land.

The flowers are unusual in form, attractive in colors and odor, and contain an abundance of nectar indicating that they depend considerably upon live agencies to assist in pollination. The nectar is so located that only certain kinds of pollen carriers, such as carpenter bees (*Xylocopa varipuncta*), a species of bumblebee; large moths;

¹ Italic numbers in parentheses refer to Literature Cited, p. 22.

² The yellow passion fruit was identified by E. P. Killip from specimens and photographs sent him by the Hawaii Experiment Station as a yellow-fruited form of *Passiflora edulis*. Later it was described as *Passiflora edulis* forma *flavicarpa* by Degener (4).

and several kinds of humming birds, are able to get it. These pollen carriers are of such size that the parts of their bodies to which pollen adheres will come in contact with both stamens and the stigmatic parts of the pistil. These pollen carriers, in their eager quest for nectar, visit many flowers frequently, and hence naturally have ample opportunity to carry pollen to many receptive stigmas. In Hawaii, carpenter bees are frequently seen visiting passionflowers, moths are rarely seen, and humming birds apparently do not exist.

It is believed that dry sunny conditions, with breezy trade winds, also aid in transmitting pollen from one flower to another and from stamens to pistils of the same flowers. There are, however, failures in pollination when both carpenter bees and breezes are present. Even hand-pollination has failed. These failures have been reported from many countries where *Passifloras* are grown. Investigation has shown that some species often have protandrous flowers, that is, the pollen of the anthers is ripe before the stigmas are ready to receive it. The protandrous habit, no doubt, is a natural condition of a number of *Passifloras* and of some other kinds of plants. It is believed to have proven a means of bringing about cross-pollination of species and possibly of varieties. The habit, in the case of the *Passiflora*, is closely associated with unusual form of floral parts, particularly of the essential organs (stamens and pistils).

The yellow passion fruit (*P. edulis flavicarpa*) is the most important and the most variable of the passion fruits in its pollination habits. Faulty pollination is undoubtedly a frequent cause of scant fruit production.

The bell-apple (*P. laurifolia*) is a prolific bloomer but invariably fails to produce fruit in proportion to the number of flowers.

The large purple strain of *P. edulis*, grown at the Hawaii Experiment Station, is a scant bearer, and some of the fruits are also defective in having a portion of the interior without seeds and edible pulp, possibly due to faulty pollination. The size of fruit and defective pollination habits are apparently transmitted in this seedling strain.

The unfruitfulness of certain *Passiflora* species is not peculiar to the Hawaiian Islands. Macmillan (9, p. 267) states that *P. laurifolia* has been in cultivation in Ceylon and parts of Asia proper for many years without fruiting. Popenoe (13, p. 242) notes that *P. edulis*, in some countries, fails to produce fruit. It has been stated (14) that the large purple variety or strain of *P. edulis* is a shy bearer.

The giant granadilla (*P. quadrangularis*), when grown in South Queensland, Australia, is reported by Barnes (3, p. 675) as often being a shy bearer, and this he attributes to the flowers being protandrous. He suggests that in the absence of insects to transmit the pollen from young blossoms to fertilize the older flowers, hand-pollination be practiced. Protandrous conditions of the giant granadilla have not been reported in Hawaii. However, cultivation of this species is rare and but little study of it has been made.

Both the yellow passion fruit and the bell-apple grow mostly at altitudes below 500 feet in Hawaii. A few trials have been made at the Kona substation, altitude 1,500 feet, and in cooperation with growers on the Island of Hawaii, at 1,000, 1,200, and 1,500 feet, but a fair set of fruit is rarely produced. Heavy yields have been pro-

duced near sea level on both the windward and the leeward side of Oahu. Plantings farther inland at 100 to 1,200 feet elevation make vigorous growth but rarely produce any comparatively large crops of fruit. A small planting made at the central station in Honolulu in 1924, at about 60 feet elevation, gave a heavy crop in the summer of 1927. The plants blossomed abundantly once or twice in succeeding years, but set very few fruits, even though carpenter bees were observed visiting the flowers, which, in this variety, are open in the afternoon only. Hand-pollination has given no better results. These unsatisfactory pollination habits are no doubt due in part to protandrous characters peculiar to certain species of *Passiflora*.

Good yields of this variety have been obtained by the station and cooperative growers, mainly in hot, dry localities where the pollen may have a chance to become relatively dry, so that it may be easily transmitted by both the breezes and the carpenter bees, and where the warm, dry air encourages early maturity of the stigmas of the pistil before the closing of the flowers at nightfall. For good growth and vigor under these conditions, irrigation would usually be required. Special attention must also be given to the arrangement of the rows in the field and to providing a type of trellis which will give the plants a chance to expose all of the flowers to strong sunlight and free circulation of the air. The warm, dry atmosphere tends to ripen the stigmas before it is too late in the afternoon for cross-pollination by natural agencies.

COMPOSITION OF FRESH PASSION FRUIT (*PASSIFLORA EDULIS*)

Results of analyses of fresh passion fruit are given in the following tabulation:

Fresh passion fruit:		Percent	Seeds on moisture-free basis—	
Rind.....	51.00		Continued.	Percent
Pulp (including seeds and juice) ³	49.00		Calcium (Ca).....	.03
Seeds.....	20.20		Phosphoric acid (P).....	.66
Juice.....	28.80		Juice as prepared from fresh fruit:	
Rind on moisture-free basis:			Water.....	79.80
Protein (N×6.25).....	9.53		Protein (N×6.25).....	.60
Crude fat (ether extract).....	.60		Fat.....	0
Nitrogen-free extract.....	52.84		Crude fiber.....	0
Crude fiber.....	30.10		Ash.....	.48
Total ash.....	6.93		Carbohydrates (by difference).....	19.10
Calcium (Ca).....	.46		Acidity (calculated as citric acid).....	2.30
Phosphoric acid (P).....	.18		Calcium (Ca).....	.005
Seeds on moisture-free basis:			Phosphoric acid (P).....	.018
Protein (N×6.25).....	12.70		Iron (Fe).....	.00034
Crude fat (ether extract).....	8.32		Calories per 100 g.....	79
Nitrogen-free extract.....	18.36			
Crude fiber.....	59.20			
Total ash.....	1.92			

In a study of the nutritive values of Hawaiian fruits by the Hawaii Experiment Station, it was noted that the passion fruit has a comparatively high sugar content and is low in calcium, phosphorus, and iron.

Hare and his coworkers (7, p. 1149) state that several species of *Passiflora* have some medicinal value, but give nothing on this

³ Fruit pulp without seeds and juice, which consists of a few thin skins, not determined.

point beyond the fact that an alkaloid had been reported. Merck's Index (10, p. 385) states that the dried flowering and fruiting tops of *P. incarnata* contain an alkaloid in small quantities.

PASSION FRUIT JUICE

Investigations as to the possibilities of extracting the juice of passion fruit and demands for the product on the local market have recently been made.

During the past 5 years, a number of experiments have been made in juice extraction by George Mellen of Honolulu, one of the station's cooperative growers. Tests with various kinds of extracting apparatus were made with both the purple passion fruit (*Passiflora edulis*) and the yellow passion fruit (*P. edulis flavicarpa*). Some improved apparatus was made for the purpose.

In 1933 and 1934, when the experimental passion fruit plantings at the Kona substation were beginning to produce fruit, Mr. Mellen's cooperation was secured in studies of extraction and marketing of juice. In addition to these data, Mr. Mellen also made available to the station records of his previous work in processing passion fruit from various localities in the Territory. Table 1 was prepared from these reports.

TABLE 1.—Results of extraction of juice from two varieties of *Passiflora edulis*

Variety of passion fruit	Date juice extracted	Fruits	Weight of fruit		Average juice per fruit	Total yield of juice
			Total	Average		
		Number	Ounces	Ounces	Fluid ounces	Fluid ounces
Purple.....	Aug. 5, 1933	775	1,240.00	1.60	0.3716	288.00
Yellow.....	Aug. 24, 1933	775	1,354.25	1.75	.8300	643.25

Results of an attempt to market the juice were as follows:

Six gallons of passion fruit juice, approximately 48 pounds, made	
13.7 gallons of soda-fountain sirup, which sold for \$2.40 per gallon.....	\$32.88
Cost of transportation, processing of fruit, materials, labor, etc.....	\$15.50
Grower's central expense, 30 percent.....	9.86
	25.36
Return to grower.....	7.52

No doubt a saving could be made if regular factory methods were established on a large scale and the grower could cultivate larger areas near the factory by improved methods.

Sales of the juice were rapid and the demand for more has exceeded the local supply.

GENERAL CULTURAL REQUIREMENTS

Most of the edible passion fruits grown in Hawaii are indigenous to tropical countries but some of them are now cultivated in such frostless sections of the Temperate Zones as are free of any considerable variation of daily temperatures. Unusually cool nights during the active growing season are very detrimental. In Hawaii,

the purple passion fruit and the sweet granadilla or waterlemon have become a part of the natural vegetation in the damp woods of practically all of the larger islands at altitudes ranging from 500 to 3,000 feet. In open forests, they spread over the treetops and often yield large crops of fruit.

SELECTION OF SITES AND SOILS

Several of the chief localities where the purple passion fruit thrives are a portion of the north slope of Mount Haleakala on the Island of Maui; parts of the districts of Hilo, Hamakua, and Kona on the Island of Hawaii; eastern slopes of the Waianae mountains on Oahu; and in the Kokee section of the mountains of the Island of Kauai. In the last-mentioned place, the crops are often large and much of the fruit is eaten by wild hogs. The mountain soils of this comparatively cool, moist locality are made up of decomposed lavas which have a liberal incorporation of humus from the forest, and with good drainage, form a very suitable growing medium for the natural growth of this exotic species.

In selecting a site for passion fruit culture, the grower should have in mind the species or variety to be grown. Both the purple passion fruit and the sweet granadilla or waterlemon will fruit freely up to an altitude of 3,000 feet, but on account of unsatisfactory pollination habits, the yellow variety of *P. edulis* requires lower altitudes, where the air is warm and comparatively dry, in order that cross-pollination may be brought about by insects and sea breezes (p. 2). If possible, the site for growing any kind of edible passion fruit should be of such exposure as to allow the rows of plants to extend from north to south, that both sides may get exposure to the sun daily at blossom time. Where irrigation is required, it may be necessary to arrange the rows somewhat differently.

None of the edible species of *Passiflora* growing at the Hawaii Experiment Station appear to be exacting in their soil requirements. The soil may vary greatly in texture and composition. Sufficient moisture and humus are the chief essentials. Wet or sour soils, which usually result from lack of underdrainage, are unsuitable. Passion fruit plants will withstand considerable drought, but growth is greatly retarded and productiveness reduced. Altitude is not so important from the standpoint of growth and prolificness as is good culture in a moist and fertile soil. In Hawaii, it is usually easier to select a moist and fertile soil at altitudes between 500 and 2,000 feet than to get the required cultural conditions on tillable land below 500 feet.

PROPAGATION

Passiflora plants require considerable growth before they are set in the field. The plants may be grown from seeds or cuttings. Most growers, however, propagate from seeds. The seed should be selected from the fruit of good quality, particularly such fruit as is free of fungus diseases. Although no serious passion fruit diseases have been observed or reported in Hawaii, the "brown spot" *Macrosporium* sp. (15) is a plant disease of considerable concern to passion fruit growers in parts of Australia, and it is possible that this and several other passion fruit diseases may be transmitted by the seed (3, p. 668).

The soft fruit pulp and juice are easily removed from the seeds after soaking in water for 24 hours. After being washed clean, the seeds are dried in the shade sufficiently to prevent the growth of mold, then stored in an air-tight container until needed. The seeds, even when properly stored, lose their viability rapidly after the first year. In fact, they give the best germination if planted soon after having been removed from the fruit. At the Hawaii Experiment Station, they are usually germinated in an ordinary propagating box about 14 by 20 inches and 3 inches deep, which will accommodate about 260 seeds.

Ordinary potting soil is generally used. It is gently pressed down to an even surface and the seed are scattered over it at about 1 inch apart, then pressed with the flat surface of a block of wood about 1 by 4 by 8 inches, such as is commonly used in propagation work, and then covered with one-half inch of soil and firmed again. The box is labeled with name and date and then set in partial shade where it will get plenty of light, warmth, and fresh air. With a liberal watering to keep the soil damp, germination will take place in 3 to 4 weeks. After reaching a height of about 2 inches, the seedlings are transferred individually to 4-inch plant pots for further growth. After about 2 weeks in a partially shaded place, the seedlings may be placed on benches outside in full sunlight. In 3 or 4 months' time, the plants will be from 6 to 10 inches high and may be set in permanent place in the field. Winter or spring planting is satisfactory in Hawaii and makes but little difference in time of fruiting. Winter planting, however, generally gives larger plants.

Raising of young plants in containers, in preference to the open nursery, avoids some loss in transplanting and produces a sun-hardened plant which makes more rapid growth in the field. In some countries the seedlings are germinated in nursery beds and when of sufficient size transplanted to the field. In Hawaii, conditions are generally such that the pot-grown methods of developing the young plants prove best.

SOIL PREPARATION

Thorough preparation of the land is very important for passion fruit culture. It should be cleared of all undesirable vegetation, stones, and the like and the soil deeply and thoroughly plowed and harrowed to as near a perfect tilth as possible. This gives a greater growing medium in which the passion fruit plants may develop active roots. It also increases the available plant food and insures better drainage. In the preparation of the soil, as in the cultivation to be done later, considerable organic matter, such as barnyard manure, panicum grass, old straw, and leguminous plants, may be worked into the soil to improve and maintain fertility.

TRELLISES AND PLANTING

Previous to setting the plants, the prepared field should be marked off in rows 10 feet apart and the trellises erected. Some growers find more time for making the trellises after the plants are set; however, this method is more difficult because care must be taken to avoid injuring the young plants.

There are several forms of trellises, the most satisfactory consisting of hardwood posts 8 feet long, set 2 feet in the ground at 15 feet apart

in the row. Soft redwood posts are unsatisfactory as they are often seriously damaged by carpenter bees. The posts should be substantially braced at the ends of the rows and at about every 200 feet in the row. Each post should have a crosspiece of strong wood 2 by 4 inches and 2 feet long, spiked on near the top for the support of two no. 8 galvanized wires which are strung tightly above and stapled, one near each end of the top edge of the crosspiece, so as to form horizontal, parallel lines about 2 feet apart (fig. 1).

The seedlings are set midway between the posts in the rows at about 15 feet apart. In doing this, each plant is taken from its container without disturbing the soil on the roots and set in the moist earth of the field. Several weeks after transplanting, each will begin to develop several vigorous branches from near the ground, and



FIGURE 1.—The purple passion fruit (*Passiflora edulis*) in field culture test at the Kona substation. The vines are set at 10 feet apart in rows and trained on trellises consisting of two heavy wires supported at 22 inches apart on crossbars of the posts.

these are allowed to reach several feet in length. The strongest one is then tied up to a temporary stake connecting with one of the wires above and the remaining branches of the plant cut away so that all of the plant food, absorbed by the root system, may be utilized by the remaining stem to produce a vigorous growth. When this growth extends to a few inches above the trellis, it is tied to one of the wires and the terminal bud cut off to force lateral branches. Only two are allowed to develop at this point, one reaching to each wire where it may divide again, spreading both ways and developing fruiting branches at intervals of about a foot. These branches are trained alternately over the wires and allowed to hang down. This arrangement distributes the weight of the vine over the two wires, utilizes all of the space between posts, and tends to give a comparatively open top for the circulation of air and the penetration of sunlight.

TILLAGE

The passion fruit field should be kept clean and free of weeds at all times. This is done mainly with the cultivator and harrow. Shallow cultivation is necessary in order to avoid injury to the root. The disk cultivator and disk harrow are best for this purpose. Deep plowing is not advisable except in the preparation of the land in the beginning and before resetting the field with new plants. The shallow cultivation also keeps the surface open for aeration and in a condition to retain the greatest amount of rainfall with the aid of the mulch turned under by the deep plowing at the time of the preparation of the field for planting.

Short-period crops of garden vegetables can be grown in the middle portion of the spaces between rows during the first year.

FERTILIZERS

The passion fruit species, which are heavy bearers, are naturally heavy feeders. The well-prepared field may be sufficiently rich in plant food for the first year or two but if the soil is very poor it should be fertilized before planting.

In the passion fruit experiments barnyard manure was applied previous to setting the plants, and this was followed by two applications of a complete fertilizer prepared especially for fruit-producing plants. This fertilizer contained 5 percent of nitrogen, 6 of phosphorus, and 3 of potash, with some calcium in the compounds carrying the 2 latter elements. The first application was 1 pound per plant, and the second, applied about 4 months later, 2 pounds per plant. These amounts should be increased considerably in the second, third, and fourth years, when heavy crops are expected.

Reports giving recommendations in reference to use of fertilizers for the passion fruit in Australia (3, p. 673) and several other countries indicate the use of a complete fertilizer similar to that used in the Hawaiian experiments.

PRUNING

Where the tops of the vines become too dense, portions may be pruned out at certain seasons. This is best done when the plants are beginning vigorous growth. Pruning during periods of dormancy has proved unsatisfactory, particularly if considerable portions of the vines are removed. In pruning, all dead leaves and branches should be removed, as well as interfering branches, which would tend to produce an unfruitful condition. Clipping excessively long branches tends to force a number of short-fruited laterals on the remaining portions. Barnes (3, p. 672) states that pruning is practiced in Australia to bring in the crop at different periods of the year when better prices may be realized.

INSECT ENEMIES AND PLANT DISEASES

Insect enemies and plant diseases of the edible passion fruit plants are not numerous. In Hawaii there is as yet only one serious enemy, the Mediterranean fruit fly. It has attacked the fruit of *Passiflora edulis* in some localities at certain seasons, while in others the fruit matures without blemish. The fruit fly punctures are made before

the fruit has matured, apparently when the rind is tender. Further growth deposits a stony mass on the inside of the rind, cutting the puncture off from the pulp inside. No maggots are found in any part of the fruit, and although the stony wall appears to prevent decay it is detrimental as it prevents the development of pulp and seed, sometimes to the extent of more than half the interior of the fruit, and results in very inferior fruit. The fruit fly punctures, which occasionally occur on the yellow variety of *P. Edulis*, also fail to produce larvae, and the rind, which is thicker and harder than that of other varieties, does not develop the stony obstruction on the inner surface. The damage to this variety is mere disfigurement of the outer surface of the fruit.

No fungus diseases have as yet been reported as attacking either plant or fruit of any of the edible Passifloras in Hawaii. Several serious diseases have caused much concern to growers in some other countries (15, p. 564).

HARVESTING AND MARKETING

The harvesting of the crop is a comparatively easy part of passion fruit production. It is also much less difficult than the handling of most other horticultural crops. The grower of any considerable amount of passion fruit should be either equipped to extract and preserve the juice or be near a market which will take large quantities of the fruit regularly. Gathering and handling should be done while the fruit is cool. Fruit intended for shipment to any considerable distance should be cut from the plants when it is just approaching the full color of ripeness. For local markets or immediate use, it may be fully ripened, when the flavor is best. Many growers prefer to let the fruit ripen and fall to the ground, picking it up each morning.

When the fruit has been gathered, it should be carefully laid in padded field boxes of about 12 by 12 by 18 inches in size. Crinkled and marred fruit does not sell well on the market, although it may be good otherwise. It should be used for local consumption or juice extraction. The juice keeps well and in good condition for the market. Properly ripened passion fruit, like most other fruit, has the best flavor. Fruit intended for market purposes should not be shipped in bags, large boxes, or barrels. The best result in shipping the fruit from the Kona substation to Honolulu, was obtained by using strong paper boxes having a capacity of about 20 pounds of fruit each.

In a study of marketing Australian passion fruit, Gregory (5, p. 43) found it highly important to handle the fruit carefully in picking, sorting, and packing, especially when intended for long-distance shipments. He also advises the growers to sort the fruit into three grades as follows: Special—large and medium-sized fruit, full of juicy pulp, and free of dummy, blemished, and diseased fruit; Standard—large and medium-sized, slightly skin-blemished fruit, full of pulp, and free of dummy and diseased fruit; Plain—small-sized fruit and all sizes of crinkled and blemished fruit, free of dummy and diseased fruit. Gregory points out the importance of growers grading the fruit to some such plan as the above, as it enables agents and buyers to understand the quality of the fruit they

are handling. He describes simple equipment for packing and different methods of arranging the fruit in the packing boxes, which makes possible quick determination of size and number of fruit per box.

USES

The uses of the passion fruit are numerous. The edible portion of the fruit, consisting of pulp, seeds, and juice, is used in fruit salads. The juice has a very individualistic flavor and is in considerable use in making refreshing soda-fountain drinks (2, p. 272). It is also used in making various kinds of cocktails, cordials, jelly, sirup, sherbet, ice cream, flavoring for icing, candy, and cake.

DESCRIPTIONS OF EDIBLE PASSION FRUITS

PURPLE PASSION FRUIT

The purple passion fruit (*Passiflora edulis*) is native of Brazil, but has spread to many other warm parts of the world where, in moist localities, it often thrives as a part of the natural vegetation. It has been considerably cultivated in Queensland, Australia, where in different localities it is known by such names as purple-fruited grana-dilla, purple passion fruit, and as passion fruit. In India it is also known as the "sweet cup" (fig. 2).

The purple passion fruit was introduced into Hawaii about 1880, where it soon became known to the Hawaiians as "liliko'i", a name given presumably from the locality on the Island of Maui where it was first grown.

There are several strains of the purple passion fruit distinguished mainly by size of fruit, a characteristic which recurs even when propagated by seed. One of these has larger purple fruit than that of the original type, but it has not proven as satisfactory because it is naturally a shy bearer. Another strain is more outstanding because the fruit is larger, of a yellow color, and the pulp and juice are more tart than that of the purple form, believed to be a true species hybrid between the purple and some other species, possibly *Passiflora ligularis*. It is described as a distinct variety, *flavicarpa*, in this publication.

DESCRIPTION

The woody perennial is a robust climber which, under favorable conditions, may spread over a large treetop 40 or 50 feet high and produce two crops of fruit per year. The seasons of maturity in Hawaii are usually summer and late fall, depending somewhat upon the nature of the season.

Leaves.—The leaves are alternately arranged, one at each node. The blade is cordate at the base, three-lobed, margin finely serrated, and the upper surface glossy green. The short leafstalk contains two semilunar glands or nectaries on the upper surface near the junction with the blade.

Flowers.—The flowers are solitary, about 2 inches across, each on a short stalk extending from a leaf axil. Inside and spreading above the whitish petals is the crown or corona composed of two series or rows of threadlike rays which have the basal halves purplish and the outer, white. There are five stamens, each terminating with heavy pollen-bearing anthers, and from the center of the flower ex-

tends the compound pistil terminating in a three-parted stigma adapted for pollination by both wind and insects.

Fruit.—The fruit is globose or ovoid, 2 to 2½ inches long and deep purple in color at full ripeness. Within the hard leathery



FIGURE 2. The purple passion fruit (*Passiflora edulis*). The ornamental vine is vigorous, flowers attractive, and the edible fruit is grown commercially in frostless countries.

rind are numerous small seeds, each surrounded by a yellowish, aromatic, juicy pulp which has a distinctly pleasing acid flavor. After the fruit matures, it falls naturally from the plant and the rind shrinks and becomes wrinkled.

YELLOW PASSION FRUIT

The yellow passion fruit (*Passiflora edulis flavicarpa*)⁴ is also known by the common name of yellow-fruited lilikoi. Although apparently closely related to the purple passion fruit, the two differ considerably. The plant is more vigorous and the flowers are larger and more fragrant, with stronger tendencies toward protandrous habit.⁵ The fruit also differs in being of a yellow color at maturity and the flavor of the pulp and juice is more clearly defined.

The Hawaii Experiment Station first received seed of the yellow passion fruit from the late E. N. Reasoner of Oneco, Fla., in 1923. Mr. Reasoner had obtained the seed in Australia when on a visit to that country. A considerable number of plants were grown by the Hawaii Station in the years following and distributed to growers in various parts of the Territory.

DESCRIPTION

The woody perennial vine is very strong when grown in favorable environments. It gives a light crop in about 18 months from seed, and two crops per year, occurring in July and October, with possibly some variation according to environment (fig. 3).

Leaves.—The leaves are almost identical with those of the purple passion fruit but appear to be a little more vigorous.

Flowers.—The flowers are similar to those of the purple variety but differ in being larger and more brilliant in color and more fragrant. They also bear two marginal glands on the outer fourth of the three outside sepals.

Fruit.—The fruit produced by seedling plants varies in size and shape from spherical to oval. The average fruits vary from 2½ to 3 inches in greatest diameter; light yellow in color at full ripeness; rind leathery, ¼ inch in thickness and white beneath the outer surface. The central cavity contains many seeds, each surrounded with a juicy, orange-colored pulp which is quite acid and of a decided aromatic flavor.

SWEET GRANADILLA OR WATERLEMON

The sweet granadilla (*Passiflora ligularis*) has been fairly well known in Hawaii for over 30 years. Wilder (18, p. 214), in 1911, stated that the date of its introduction to Hawaii, and by whom, was not known. In parts of the Island of Hawaii, however, it has been growing for many years as a part of the natural vegetation.

The species was erroneously called *P. laurifolia* in Hawaii. A more thorough study of its specific characters showed it to be *P. ligularis*. The common name "waterlemon" is also misused, as long ago that name was applied to another species in some English-speaking countries (2, p. 445; 9, p. 267).

In recent years the sweet granadilla has spread to many localities where there are warm, moist woods adapted to its natural growth (fig. 4). Such conditions usually range from near sea

⁴ See footnote 2.

⁵ The anthers shed their pollen before the stigmas are in a condition to receive it, and without fertilization of the ovaries there is a failure to set fruit.

level to about 3,000 feet in altitude. In season—July, August, and possibly September—the fruit is frequently on sale in local markets and sells for a fair price. The fruit is of good quality when fresh, and is wonderfully refreshing when eaten out of hand in the



FIGURE 3.—The yellow passion fruit (*Passiflora edulis flavicarpa*) is very exacting in its requirement but is the favorite passion fruit of the sunny, dry localities at lower altitudes in Hawaii.

wild, but soon deteriorates after being picked. Its main use is as a dessert fruit. The fruit is grown to some extent in its native countries, Mexico and parts of Central America, and meets with considerable favor in the markets of these countries.

DESCRIPTION

The plant is a perennial, propagated mainly by seeds and climbs by means of tendrils. Under good conditions, it is a vigorous climber, and when allowed to run wild, spreads over trees, fences,



FIGURE 4.—The sweet granadilla (*Passiflora ligularis*) grows freely as a wild climber of the cool, moist woodland in Hawaii where the fresh, delicious fruit is highly prized.

and buildings, but is easily confined to a trellis when grown in cultivation. It is valuable not only for its fruit, but its foliage and flowers are ornamental. The stems are smooth, slightly woody at the base.

Leaves.—The leaves are large, light green, heart-shaped, and with entire margins. The leafstalks bear three pairs of ligular glands, i. e., glands mounted on ligules or strap-shaped stalks, hence its specific name *ligularis*.

Flowers.—The flowers have a sweet musklike odor. They are usually solitary, 3 inches across; sepals and petals greenish; the corona white with zones of white and purple.

Fruit.—The fruit is oval or slightly elliptical in form, about 3 inches long, and of an orange-brown or sometimes partially purple color and with numerous whitish specks. The shell is firm enough to make it possible to ship the fruit long distances without injury. The seeds are numerous, and each is surrounded with a light-colored, juicy pulp, which, with the seeds, is the edible portion having a pleasing subacid flavor and pleasant odor.

GIANT GRANADILLA

This species of passion fruit (*Passiflora quadrangularis*) is native of the Tropics of South America. It is now widely distributed throughout the warm, moist parts of the earth, where it is grown as an ornamental and for its edible fruit. The giant granadilla has several other names, such as "common granadilla", the "granadilla vine", and the "square-stalked passion flower", according to Ochse (11, p. 101). The word "granadilla" is from the Spanish and is applied in different parts of the Tropics to several other species of *Passiflora*, all of which have less robust vines and comparatively of smaller fruit. The species name *quadrangularis* has reference to the four-angled stems (fig. 5). There are several strains varying mainly in size of fruit. Formerly the strain with the largest fruit was believed to be a different species and was botanically named *P. macrocarpa*, but investigation has shown lack of sufficient specific characteristics and the name is now given as synonymous with *P. quadrangularis* by Bailey (2, p. 445). Popenoe (13, p. 247) recognizes a form which has foliage blotched with yellow.

The ripe fruit of the giant granadilla makes a wholesome delicacy by mixing pieces of the white, semisolid portion of the rind with the juicy, purple pulp from around the seeds and serving with sugar and cracked ice (11, p. 102). When fully ripened the giant granadilla is one of the most highly flavored tropical fruits. It is eaten either alone or used in combination with papaya, pineapple, and banana, and with the juice of lemon or lime to form a fruit salad. It may be used in making sherbets. Macmillan (9, p. 268) states that both the preripec fruit and the root, which is usually fleshy, are cooked and eaten as vegetables. Other uses of the fruit have been reported (14, p. 55).

The methods of propagation are similar to those used for all species of *Passiflora* bearing edible fruit (p. 6).

The giant granadilla is quite exacting in its requirements. For successful growth it requires a deep, fertile, well-drained soil and a comparatively warm temperature, varying but little from day to night. In Hawaii it is occasionally found in home gardens up to altitudes of about 1,500 feet. In parts of India it is reported to be in cultivation up to 3,000 feet, and it is also grown to a considerable

extent in the Dutch East Indies, where in some particularly favorable areas it grows wild as an escape. For good growth each plant should have a space 8 to 10 feet across, and in field culture the plants should



FIGURE 5.—The giant granadilla (*Passiflora quadrangularis*) is a coarse, angular-stemmed vine with large leaves and fruit, the edible fruit often 8 to 10 inches long and weighing as much as 8 pounds.

be set in rows 8 or 10 feet apart each way and trained on rather open overhead trellises, which will give a horizontal spread at 6 or 7 feet above the ground, allowing the fruit to hang suspended beneath and have both space and protection for natural growth.

DESCRIPTION

The plant is a coarse perennial with a more or less fleshy root, woody stem, and green four-angled branches. It climbs by means of tendrils.

Leaves.—The leaves are alternately arranged, 6 to 8 inches long, yellowish green, ovate or elliptical, cordate at base and margin entire; leafstalk angular, contains 3 pairs of nectaries or glands, and the stipules are relatively broad.

Flowers.—The flowers are very attractive in color and fragrance; 4 to 5 inches across; flower stalk short and bearing 3 large green bracts near the base of the receptacle; calyx segments 5, broad, thick, spongy, greenish outside and white or pinkish within; petals 5, red above, white or pinkish below; corona (a crownlike structure) consisting of 4 or 5 whorls or circular rows of rays, the 2 or 3 inner whorls very short and white blotched with red, 2 outer rows consisting of coarse stringlike rays forming a fringe, reddish at the base, the remainder cross striped with purple and white, and the outer halves of the rays more or less crooked from having been folded in the bud; stamens 5, rising above the central column, anthers broad and pivoted on the filament from the upper side. The ovary of the pistil is mounted on a gynophore (a stalk raising the pistil above the stamens) and the style is divided into 3, sometimes 4 or 5 parts, each of which terminates into a rather large, globular or reniform stigma.

Fruit.—The fruit is oval-oblong or elliptical, 9 or 10 inches long, often weighing 4 or 5 pounds; skin thin, light green or yellowish green when ripe; rind about $1\frac{1}{2}$ inches thick, central cavity containing many seeds, each surrounded with a subacid purplish or yellowish, juicy pulp of pleasing flavor. Seeds flattish oval in outline, three-eighths inch long and of a brownish color.

BELL-APPLE

The bell-apple (*Passiflora laurifolia*) (fig. 6) has several other common names, as "sweet-cup", "waterlemon", "Jamaica honeysuckle", "Pomme d'or", and some have called it the "yellow granadilla fruit" (13, p. 248). These names tend to cause confusion. The entire, elliptical leaves, unusual for *Passiflora*, are somewhat like those of the well-known laurel which was probably the guide for the specific name, as given by the botanist Linnaeus, who named it.

DESCRIPTION

The bell-apple plant is a handsome and moderately vigorous climber which is most valuable for covering unsightly structures. Its bright green foliage, beautiful flowers, and pendular, golden fruit are very ornamental. In Brazil and parts of the West Indies, where it is apparently indigenous, it is cultivated mainly for the fruit, which has an agreeable subacid flavor. The plants are easily propagated by seeds and by cuttings. In Hawaii, as in India and Ceylon, the plants blossom freely but mostly drop without setting the fruit, possibly because of insufficient pollination (9, p. 267).

Leaves.—The vine is a glabrous climber with alternately arranged elliptical or long-elliptical leaves, each with pointed apex, entire margin, 6 to 8 inches long, and with a single pair of petiole glands near the point of attachment with the base of the leaf blade.



FIGURE 6.—The bell-apple (*Passiflora laurifolia*) is an attractive arbor vine—the foliage, flower, and edible fruit are very ornamental. It is interesting to note that the bright orange-colored fruit is unusual in being surmounted with three rich green bracts.

Flowers.—The large, handsome, fragrant flowers are 3 to 4 inches across. They contain a beautiful arrangement of green, white, pink, red, and violet tints.

Fruit.—The fruit is ellipsoidal, orange-yellow, 2.5 inches long and unusual in being surmounted by three large green bracts. The rind or soft shell surrounds a white spongy covering of the edible portion which consists of juicy pulp and seeds.



FIGURE 7.—The sweet calabash (*Passiflora maliformis*) is very ornamental. The hard rind of the edible fruit is difficult to open. The species is said to have particular value in crossbreeding work.

SWEET CALABASH

The sweet calabash is botanically known as *Passiflora maliformis* Linn. Popenoe (13, p. 249) states that it is native of tropical America where it is called "curuba" or "kuruba", and that it is

cultivated in the West Indies and Colombia. Wester (16, p. 7) reports its cultivation in Brazil and Ecuador for its aromatic, palatable pulp. Grisebach (6, p. 293), who made a considerable study of *Passiflora*, describes the species botanically and gives its habitat as the West Indies and New Granada.

The common English name probably originated from the nature of its fruit, the outer covering of which is hard like the shell of a gourd, and the specific name *maliformis* also has reference to the fruit, which is shaped like the common apple (*Pyrus malus*).

DESCRIPTION

In Hawaii the species has been grown in private gardens mainly for ornamental purposes for which it is conspicuously suited. Each bud is enclosed in a large bladdery covering formed by the three bracts, which, upon blooming, open and form a cream white background for the more highly colored floral parts (fig. 7.) The Hawaii Experiment Station is cultivating it for use in plant-breeding work because the species has very prolific habits and is apparently quite immune to the attacks of certain insect pests and plant diseases known to infest some other passion fruit plants. It may be possible to develop a hybrid having these resistant qualities and a better fruit. The comparatively small size and hard shell of the sweet calabash are objectionable characters, particularly when the fruit is in competition with other species and varieties already being grown in Hawaii.

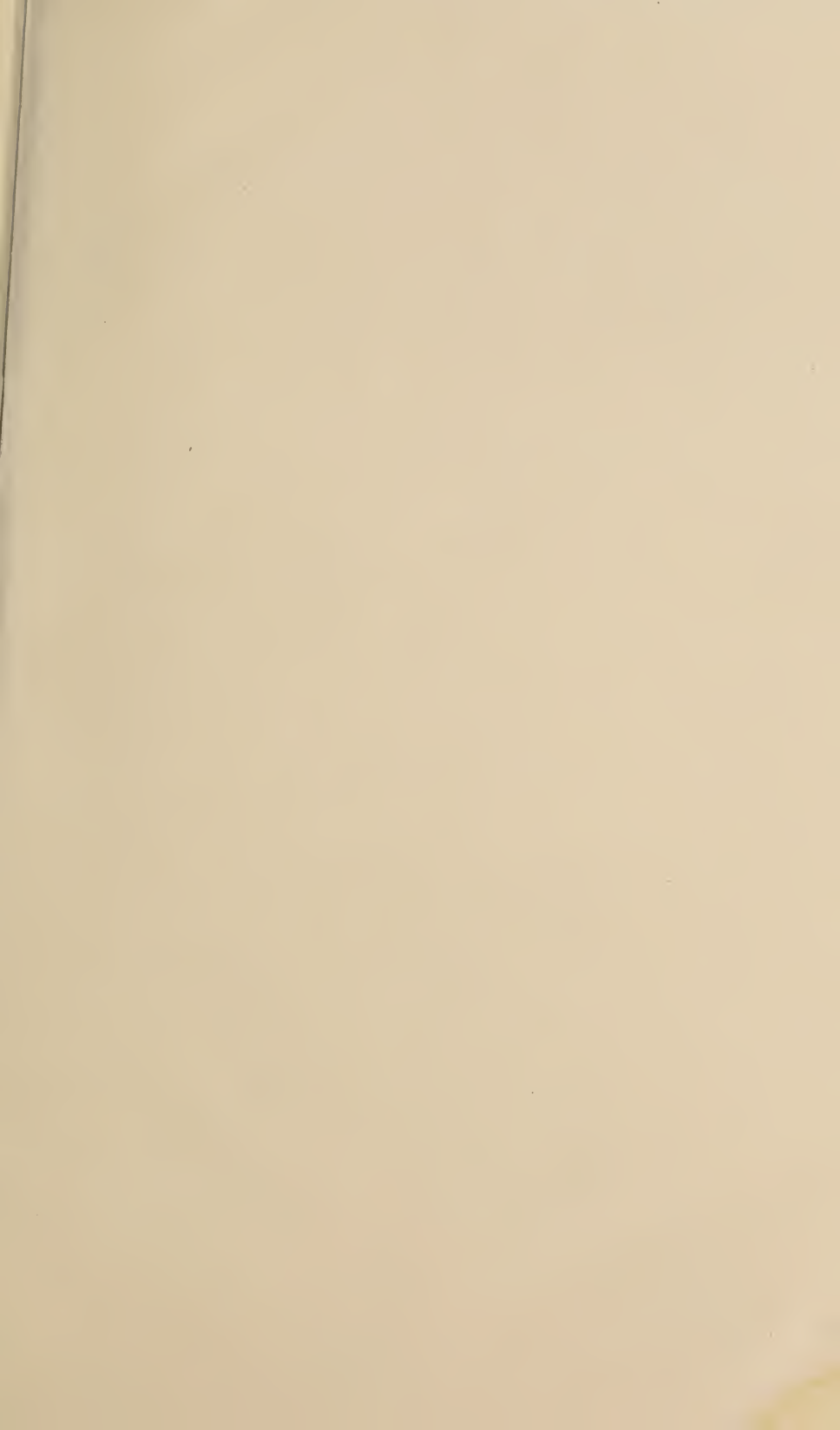
Leaves.—The vine of the sweet calabash is relatively small and slender. The leaves are from 4 to 6 inches long, ovate to ovate-oblong, with an apex which terminates in a small, sharp, recurved point; leafstalk biglandular above the middle.

Flowers.—Tendrils and flowers arise from the axils of leaves, flower stalk slim, flowers about 4 inches across, attractively marked with tints of white, purple, and blue; sepals prominently keeled behind, light green, and dotted with reddish brown in front; petals rudimentary and essential organs (stamens and pistils) very similar to those of other passion fruit flowers.

Fruit.—The fruit is oval, 1.75 inches long, light green turning to brownish at full maturity and rind hardening into a shell; seeds small, flat, and surrounded with a grayish juicy pulp of subacid flavor.

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